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(54) Title: ELECTRON SOURCE AND APPLICATIONS OF THE SAME

(57) Abstract

The electron source comprises a uniform microscopically flat carbon nanotube film parallel to which and close to which are one or several perforated thin conducting plates, which are electrically insulated from the microscopically flat carbon nanotube film. An electric field at the microscopically flat carbon nanotube film, provided by a voltage applied to the microscopically flat carbon nanotube film and to the conducting plates causes electron emission from the microscopically flat carbon nanotube film by the field emission effect resulting in an electron beam which passes through the perforations in the conducting plates. The electron beam intensity is determined by the electric field at the carbon nanotube film which can be regulated with the voltages applied to perforated thin conducting plates.

ELECTRON SOURCE AND APPLICATIONS OF THE SAME

This invention relates to an electron source and to applications of the same.

Electron sources have a broad spectrum of applications. They are used for example to provide the electrons for the electron guns in cathode ray tubes, X-ray tubes, in electron microscopes and for various research purposes such as spectroscopies involving electron beams. Conventional electron sources are usually of the thermionic type, where a material is heated to high temperatures thereby causing the evaporation of electrons from the surface. Alternatively electron sources are also of the field emission type where electrons are extracted at high voltages from sharp tips. The electron energy spread from these tips is narrower than that from thermionic emitters.

As is known, a conducting rod with a sharp tip will emit electrons when the electric field at the tip is sufficiently strong. Strong fields will occur if the tip opposes a counter electrode and a voltage is applied between the tip and the counter electrode. The effect relies on the property that electric fields are concentrated at sharp tips hence the electric field at the tip is amplified by a factor which depends on the geometry of the emitter and its surroundings. When the electric field becomes sufficiently large, then electrons will be extracted from the tip due to a quantum mechanical tunnelling phenomenon, also known as field emission. Physically the process of field emission is described by the Fowler-Nordheim equation which relates the field emission current density from a material to the electric field strength. Field emitting tips fabricated from metals operate reliably only in stringent vacuum conditions, for example less than 10^{-9} Torr. Alternatively, carbon fibers with diameters on the order of 10 microns have also been shown to emit electrons by the field emission effect. These fibers have the advantage that they also function in this respect under

medium vacuum conditions, for example 10^{-6} Torr providing currents up to 10 μA, however problems with reproducible production and rapid deterioration reduces their commercial value. Carbon fiber bundles have also been used for these purposes, where more than one fiber will emit electrons.

The aim of the invention is to remedy to the disadvantages of the existing electron sources and to provide a low cost large area ultra thin general purpose electron source, to be used for example for the production of flat two-dimensional displays.

To this end, the electron source according to the invention is provided with a uniform microscopically flat carbon nanotube surface, parallel to which and close to which are one or more perforated thin conducting plates, which are electrically insulated from the uniform microscopically flat carbon nanotube surface by perforated insulating spacers.

The words microscopically flat surface here means that the roughness of the surface does not exceed 10% of the distance from the surface to the first conducting plate.

In vacuum a negative voltage with respect to the conducting plate(s) can be applied to the uniform microscopically flat carbon nanotube surface causing electrons to be emitted from the nanotube surface. These electrons pass through the perforations in the conducting plate(s) after which they are ejected into the vacuum chamber thereby producing an electron beam. By varying the voltages applied to the nanotube surface and to the plate(s) the electron beam intensity and the energy of the constituent electrons can be varied.

The invention relies on the following properties of the uniform microscopically flat carbon nanotube film: (1) the field amplification factor must be very large i.e. greater than 100; (2) it is flat on the micron scale over at least 5 cm^2; (3) it is uniformly covered with carbon nanotube

containing material; (4) it is electrically conducting and uniform in its electrical conductivity properties.

The invention further relies on the following properties of the perforated conducting plates: (1) they must be electrically insulated from the carbon nanotube surface; (2) they are preferably parallel to the carbon nanotube surfaces, over areas corresponding with the emitting surface; (3) the diameters of the perforations in the first conducting plate is preferably no greater than twice the distance between the plate and the carbon nanotube surface.

The invention further relies on the following properties of the insulating spacers: (1) their thickness is preferably between 1 and 100 microns; (2) they can withstand the electric fields at their surfaces without electrically breaking down.

Compared with previous electron sources, the electron source according to the invention has namely the following advantages: (1) it provides an ultra thin electron source which operates at room temperature with an overall thickness ranging from not more than 20 microns to not less than 200 microns and with an area ranging from not more than 0.1 mm^2 to not less than 5 cm^2; (2) it can operate at lower electric field strengths compared with conventional field emission electron sources; (3) it operates reliably at much higher pressures, for example 10^{-6} Torr, compared with conventional field emission electron sources; (4) it can be used to produce very large area electron emitting surfaces; (5) it can be used to produce extremely compact electron sources; (6) its production costs are very low; (7) there are few restrictions on its geometry, for example both planar and non-planar geometries are feasible; (8) it can be used to illuminate phosphor screens at close proximity, as may be used for example, for flat cathode ray displays; (9) it can be used as an economical alternative electron source for devices which utilise conventional electron sources.

Other related objects and advantages of the present invention will be apparent from the following description, given by way of example and which refers to the drawings on which:

Figure 1 is a schematic cross section of a first embodiment of the electron source according to the invention.

Figure 2 is a diagram of the current versus voltage characteristics for the electron source of Figure 1.

Figure 3 is a diagram of the current output of the electron source of Figure 1 as a function of time.

Figure 4 is a schematic cross section of an application of the electron source according to the invention as a source of focused electrons.

Figure 5 is a schematic cross section of an application of the electron source according to the invention in a configuration suitable for producing modulated electron beams.

Figure 6 is a schematic cross section of an electron source according to the invention in a configuration suitable for monitoring and regulating the electron beam intensity.

Figure 7 is a top view of a first application of an electron source according to the invention to a large surface ultra flat cathode ray display.

Figure 8.1 is a top view of a second application of an electron source according to the invention to a large surface ultra flat cathode ray display.

Figure 8.2 is a cross section of the display of Figure 8.1.

Figures 8.3 to 8.5 are top views of the main components considered separately of the display of Figure 8.1.

Figure 9 is a schematic cross section of an example of electron source according to the invention using other electron optics.

Figure 10 is a schematic cross section of another example of electron source using the electron optics as in Figure 9.

The microscopically flat carbon nanotube film can be produced according to the following procedure based on the procedure described by W.A. de Heer et al. in Science, Vol. 268, page 845-847, 12 May 1995. The steps involve (1) production of nanotube containing carbonaceous material, (2) dispersion of the nanotube containing carbonaceous material in a solvent, for example ethanol, (3) sedimentation of the suspension, (4) deposition of the suspension on a micropore filter, (5) pressure transfer of the deposit on a polymer substrate. In more details the steps can be: (1) production of a carbon nanotube containing material based on a process described by T.W. Ebbesen and P.M. Ajayan in Nature, Vol. 358, page 220, 1992, where an arc is sustained in a 500 Torr helium atmosphere between an anode consisting of a graphite rod, for example 6 mm in diameter and 5 cm in length and a for example 2 cm diameter graphite cathode, using full wave rectified 50 Hz current of for example 70 A, at a voltage of for example 20 V for a time of for example 15 min, by which a cylindrical deposit with a length of for example 1 cm is produced on the cathode, consisting of a soft core about 3 mm in diameter surrounded by a hard outer shell, whereafter the soft core is recovered; (2) a quantity of the soft core material, for example 10 mg, is mixed with for example 100 cc of spectroscopically pure ethanol, which is ultrasonicated, for example for 10 min, in an ultrasonic bath; (3) the resulting suspension is left to sediment for example for 30 min; (4) the sediment is discarded and the remaining suspension is recovered; (5) the remaining suspension is drawn through an inorganic membrane filter (for example Anodisc 25 Cat. No. 20021S50, 0.2 micron pore, 25 mm diameter), using a water pump resulting in a flat black uniform coating on the filter, after

which the coated filter is removed and allowed to dry for example either in air for several hours or in a circulating hot air oven at 100 °C for 30 min; (6) the coated side of the filter is covered with a 2 cm square of 0.1 thick Teflon tape; (7) the resulting Teflon covered filter is sandwiched between two 5 cm square 1 mm thick Delrin sheets, and subsequently compressed with a force of 30000 N which is applied uniformly to the sandwiched assembly, by which the black deposit on the filter is transferred to the Teflon film.

This procedure produces a uniform microscopically flat β aligned carbon nanotube film on the Teflon film which has a shiny black appearance and which is flat on the micron scale and uniformly coats the Teflon film with aligned carbon nanotubes over the area of the covered surface, for example 5 cm^2 with an electrical resistance in the range of 200 Ohms per Square to 800 Ohms per Square, preferably 500 Ohms per Square. By lightly rubbing the flat β aligned carbon nanotube film with a sheet of Teflon a flat α aligned carbon nanotube film is produced.

A variant of the procedure involves: steps (1) followed by (2) followed by (3) followed by the following steps 4.1 to 4.3: (4.1) the remaining suspension is dried in a crucible and heated at a high temperature, for example 650 °C, in air, for a duration of time, for example 30 min; (4.2) the black powdery material is recovered and heated, for example to 2000 °C, in vacuum, for a duration of time, for example 30 min; (4.3) the resulting material is treated as described in (2) followed by (3), (4), (5), (6) and (7). With this procedure, the nanotubes are opened by oxidation and regraphitized and β aligned on the Teflon film, producing a uniform β aligned opened regraphitized carbon nanotube film.

The electron source illustrated (not to scale) in Figure 1 comprises an optically flat support 11, for example in glass, a uniform microscopically flat β aligned carbon nanotube film 12, a perforated insulating spacer 13, for example in mica,

with a thickness in the range of 0.005 mm to 0.2 mm, preferably 0.02 mm, a perforated conducting thin sheet 14 with multiple perforations each which have a diameter preferably not larger than twice the spacer thickness, for example a 200 mesh (75 μm) 3 mm diameter copper electron microscope grid. The spacer is bonded to the microscopically flat carbon nanotube film with a suitable adhesive, for example cyanoacrylate. The perforated conducting sheet is bonded to the insulating spacer with a suitable adhesive, for example cyanoacrylate. An electrical lead is connected directly to the uniform microscopically flat carbon nanotube film using a conducting adhesive, for example colloidal silver paint, and an electrical lead is connected to the perforated conducting thin metal sheet. Applying a negative voltage, for example in the range of 0 V to -1000 V, to the uniform microscopically flat carbon nanotube film produces an electron beam which is detected using a metal plate 15, for example a copper plate, located between 0.1 mm to 10 cm in front of the electron source.

As can be seen from Figure 2, the current versus voltage curve 21 measured for an electron source as described in Figure 1, for 1 mm^2 of electron emitting surface, where the uniform microscopically flat carbon nanotube film was β aligned, accurately follows the Fowler-Nordhiem equation (see for example C.A. Spindt et al. J. Appl. Phys. 5248 Vol. 47, No. 12, pages 5248-5263) which describes the current versus voltage characteristics for field emission. Changing the insulating spacer thickness modifies the curve consistent with the Fowler-Nordheim equation so that for thinner spacers proportionally lower voltages are required to obtain the same current and for thicker spacers proportionally higher voltages are required to obtain the same current. Mathematical analysis of the curve 21 using the Fowler-Nordheim equation and assuming that the workfunction of the emitters is 5.0 eV (i.e. corresponding to the workfunction of graphite) reveals that the electric field at the current emitting tips of the carbon nanotubes on the uniform β aligned carbon nanotube film

produced according to the procedure described above is a factor (called the field amplification factor) of 1300, and typically between 300 and 1500 times the average applied field. In comparison, for standard field emitting tips, the electric field strength at the tip is about 10 times the voltage applied to the tip divided by the tip to counter electrode distance and consequently the uniform β aligned carbon nanotube film requires fields which are lower by about a factor of 100 compared with conventional tips to produce field emission. The very large field amplification factor of the uniform aligned carbon nanotube films is a hitherto unknown property of the film and is essential for the functioning of the electron source according to the invention, which consequently can operate at much low voltages compared with conventional field emitters when similar emitter to counter electrode distances are used and similar current are drawn in both cases.

Similar results, however with higher currents have been obtained replacing the β aligned microscopically flat carbon nanotube film with a β aligned microscopically flat opened regraphitized carbon nanotube film; similar results, however with lower currents have been obtained replacing the β aligned microscopically flat carbon nanotube film with an α aligned microscopically flat carbon nanotube film. These similarities suggest that uniform microscopically flat nanotube films produce large field emission currents at low voltages. They also suggest that β aligned microscopically flat carbon nanotube films are superior in their field emission properties than α aligned microscopically flat carbon nanotube films and hence that the degree of alignment of the carbon nanotubes on the film is important but not crucial for the invention.

As shown in Figure 3, the measured current as a function of time for constant applied voltage 31 in the electrical configuration of Figure 1 indicates that the fluctuations in the current are in the order of 10%. Applying a feedback regulation between the current and the voltage, accomplished

by passing the current through a resistor, with a resistance in the range of 100 Ohms to 1 MOhm, for example 10 kOhms, and electronically inverting and amplifying the voltage across the resistor and applying the amplified inverted voltage to the microscopically flat carbon nanotube film, and applying 0 V to the conducting plate 14, stabilizes the current to within 2% or less than 2% as shown by curve 32.

The electron source illustrated (not to scale) in Figure 4 is an electron source of the type shown in Figure 1, with additional electron optics to produce an electron gun which produces a focused electron beam, which consists of the electron source as described in Figure 1 with in addition two perforated metal plates 41, 42 which have holes, for example 1 mm in diameter, separated by perforated insulating spacers 43, 44. All elements (i.e. 41, 42, 43, 44) are for example 0.2 mm thick. Applying a voltage of for example -500 V to the microscopically flat carbon nanotube film 40, -500 V to the perforated plate 41 and 0 V to the perforated plate 42 produces a focused electron beam. The focal point of the focused beam can be varied by adjusting the voltages on plates 41 and 42.

The application of the electron source illustrated (not to scale) in Figure 5 represents a configuration suitable for producing an electron beam of which the intensity can be modulated. This configuration comprises a microscopically flat carbon nanotube film 12, a perforated insulating spacer 13, a grid 14 (for example 50 mesh, i.e. 300 μm), a second insulating spacer 53 similar to 13 and a second grid 54 (for example 200 mesh, i.e. 75 μm). Applying a voltage of for example -500 V to the microscopically flat carbon nanotube film 12 and 0 V to the two grids 14 and 54 produces an electron beam. Applying a potential of for example -200 V to the first grid 14, while keeping the second grid 54 at 0 V reduces the electron beam current. When subsequently a voltage of for example +200 V is supplied to the second grid 54, the electron beam current is increased. The effect of the

potentials applied to grids 14 and 54 is to modify the electric field at the microscopically flat carbon nanotube film and consequently affect the electron emission of the same.

An example of electron source in a configuration suitable for producing an electron beam of which the intensity can be modulated and where the electron beam intensity can be monitored is represented (not to scale) in Figure 6. This configuration is similar to the configuration illustrated in Figure 4, with an additional grid 61, for example 50 mesh (i.e. 300 μm), and perforated insulating spacer 62, for example 0.1 mm thick. In this configuration a fraction of the electron beam is intercepted by the grid 61 and the resulting current is proportional to the electron beam current, which consequently can be used in a feedback loop as described in Figure 3 to regulate the voltages of the grids 63 and 14 and which can consequently be used to stabilize the electron beam as described in Figure 3.

Figure 7 shows a schematic example (not to scale) of multiple duplicates of the electron source according to the invention in the configuration described in Figure 6, mounted on a single sheet of aligned microscopically flat carbon nanotube film 79, which are arranged in a two dimensional array consisting of rows and columns. The first grids of the sources in a row 70, 71, 72 of the array are mutually electrically connected and are called the enable electrodes. The second grids of the sources in a column 73, 74, 75 are mutually connected and are called the gate electrodes. The third grids of the sources in a column 76, 77, 78 of the array are mutually connected and are called the monitor electrodes. A three by three array is represented in Figure 7. However the pattern can be repeated indefinitely to cover the entire surface of the single sheet of the microscopically flat carbon nanotube film. In such an arrangement, by applying a voltage of for example -300 V to the microscopically flat carbon nanotube film 79 and an enabling voltage of 0 V to enable

electrode 70 and applying for example -200 V to enable electrodes 71 and 72, and applying a voltage of 0 V to the gate electrode 73 and applying a voltage of for example -200 V to gate electrode 74, and applying a voltage of 0 V to gate electrode 75, causes elements 710 and 712 to emit electrons while all other elements of the array do not emit electrons. Furthermore, the electron currents of elements 710, 711 and 712 can be monitored by measuring the current flowing through monitor electrodes 76, 77 and 78 respectively, and these currents can then be used in a feedback loop to adjust the electron beams emitted from elements 710, 711 and 712 respectively. Thus by successively applying enabling voltages to successive enabling electrodes, while simultaneously supplying appropriate gate voltages to all gate electrodes, rows of emitters will simultaneously be activated, and each of those activated elements can be regulated using their corresponding monitor electrodes. If, furthermore, a phosphor screen is placed in front of this array, a two dimensional image can be produced.

Figures 8.1 to 8.5 show a schematic example (not to scale) of a two dimensional array of an electron source according to the invention consisting of a series of parallel mutually electrically insulated strips of microscopically flat carbon nanotube film (Figure 8.3); a perforated thin insulating sheet where the positions of the perforations correspond with the strips of microscopically flat carbon nanotube film as indicated (Figure 8.4); and a series of parallel conducting strips supplied with grids located at positions corresponding to the perforations in the thin insulating sheet (Figure 8.5). As represented in Figure 8.1, the assembled structure constructed by superimposing the elements represented in Figures 8.3, 8.4 and 8.5, such that the strips of microscopically flat carbon nanotube film 83 lie directly beneath the perforations in the insulating sheet 84, which in turn lie directly beneath the grids 85. In this configuration a column of the array, for example 81, is enabled by supplying a sufficiently large negative voltage to 81, and other columns

of the array, for example 82 are disabled by supplying a less negative voltage than that supplied to 81. The different elements of array are activated by supplying separate voltages to the parallel conducting strips. Hence, each element of the column of elements along the strip of microscopically flat carbon nanotube film emits electron beams with intensities which depend on the voltage supplied to each of the parallel conducting strips. Furthermore, the intensity of an individual electron beam in the array may be monitored by determining the current through the corresponding parallel conducting strip, and this current may be used to stabilize and regulate the electron beam of each of the enabled elements by regulating the voltages supplied to the parallel conducting strips using a feedback mechanism of which an example is given in Figure 3. Supplying enabling voltages sucessively to the parallel mutually electrically insulated strips of microscopically flat carbon nanotube film and similtaneously supplying voltages to the parallel conducting strips produces successive columns of electron beams to be produced which can be projected on to a phosphor screen 89 (see Figure 8.2).

Figure 9 schematically shows an example of electron source according to the invention using modified electron optics. In this configuration, a perforated conducting layer 92 is in electrical contact with the microscopically flat carbon nanotube film 12. This layer is covered with a perforated insulating layer 13 and a perforated conducting layer 14. A positive potential with respect to conducting layer 92 is applied to conducting lyaer 14 in order to produce an electric field at the carbon nanotube film, so that electrons are ejected from the film. The electron optical properties of this configuration insure that the electric field is uniform over the emitting part of the surface of the carbon nanotube film. Furthermore, the conducting layer 92 insures that the electric field at and near the contact of the nanotube film and the conducting layer 92 is strongly reduced thereby inhibiting potentially damaging arcing discharges.

The sizes of the perforations and the thickness of the elements 92, 13 and 14 may be chosen to produce a focused electron beam. For these purposes, the thickness of the insulators and conducting layers should range from 1μm to 1 mm and the perforations sizes should range from 1μm to 1 mm. For example, the perforation size can range from 0.1 to 10 times the thickness of element 13.

Figure 10 schematically shows an example of electron source according to the invention using modified electron optics as in Figure 9, with in addition a perforated insulating layer 106 and a perforated conducting layer 107. The purpose of layers 106 and 107 is to further control the electron beam in a manner similar to the example of Figure 4. Additional layers of perforated insulators and perforated conductors may be used.

CLAIMS

1. An electron source of the field emission type, comprising at least one electrode (12), provided with a plurality of carbon fibers, at least one counter-electrode (15), separated from said electrode, and a voltage source connected between said electrode and said counter-electrode, said voltage source being capable of applying between said electrode and said counter-electrode a sufficiently high negative voltage to generate, at the tip of at least one end of said fibers, a sufficiently strong electric field for causing said tip to emit electrons towards said electrode, characterized in that said carbon fibers consist of carbon nanotubes forming a uniform microscopically flat layer, applied on an electrically insulating substrate (11), and in that at least one electrically conducting perforated plate or grid (14) is interposed between said layer of carbon nanotubes and said counter-electrode, said plate or grid being parallel to the surface of said layer and separated therefrom by at least one insulating spacer member (13).

2. An electron source according to claim 1, wherein the substrate is an optically flat substrate.

3. An electron source according to claim 1, wherein the substrate is a curved substrate and wherein the insulating spacers and conducting plates or grids are substantially mutually parallel.

4. An electron source according to one of claims 1 to 3, comprising an additional perforated plate (92) in electrical contact with said layer (12) of carbon nanotubes and situated between said layer of carbon nanotubes and said spacer member (13).

5. An electron source according to one of the preceding claims, comprising additional electron optics consisting of

thin perforated plates (41, 42) separated by thin perforated insulating plates (43, 44) to produce a focused electron beam.

6. An electron source according to one of claims 1 to 4, comprising at least a further perforated insulating spacer (53) and a further grid (54), whereby the electron beam intensity can be modulated.

7. An electron source according to claim 6, comprising a further perforated insulating spacer (62) and a further grid (61), whereby the intensity of the electron beam can be modulated and monitored.

8. A two dimensional array of electron sources as in claim 7, wherein the electron sources are mounted on a single microscopically flat carbon nanotube film, and wherein the first grids of the sources in a row (70, 71, 72) of the array are mutually electrically connected, the second grids of the sources in a column (73, 74, 75) are mutually connected and the third grids of the sources in a column (76, 77, 78) of the array are mutually connected.

9. An electron source according to one of claims 1 to 8, further comprising an electronic feedback device arranged to measure the emitted current at the nanotube surface (12) or at the counter-electrode (15) and to adjust the voltage(s) (V) applied to the nanotube film and/or to the conducting plates, with the purpose to stabilize and regulate the electron beam.

10. A two dimensional array of electron sources as in claim 1 comprising the following successive layers of elements:
i. a first plurality of mutually insulated parallel strips of microscopically flat carbon nanotube film;
ii. an insulating perforated plate;
iii. a second plurality of mutually parallel and mutually insulating conducting perforated strips, which are perpendicular to the strips of said first plurality described in i.

11. A two dimensional array of electron sources according to claim 10 comprising an electronic feedback device arrange to measure the emitted currents at the nanotube surfaces or at the counter-electrode and to adjust the voltages applied to the nanotube films and/or the conducting plates, whereby the electron beam is stabilized.

12. A two dimensional array of electron sources according to claim 11, further comprising one or more layers of perforated conducting plates and insulators with the purpose of stabilizing and focusing the electron beams.

13. A two dimensional array of electron sources according to claim 11, further comprising one or more layers of perforated conducting plates and insulators with the purpose of modulating the intensity of the two dimensional array of electron beams using an electronic feedback system between the emitted currents and the applied voltages.

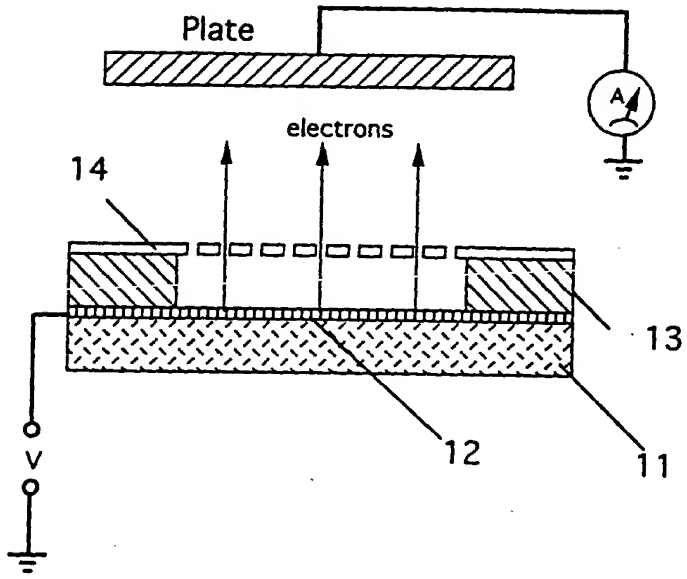

Fig. 1

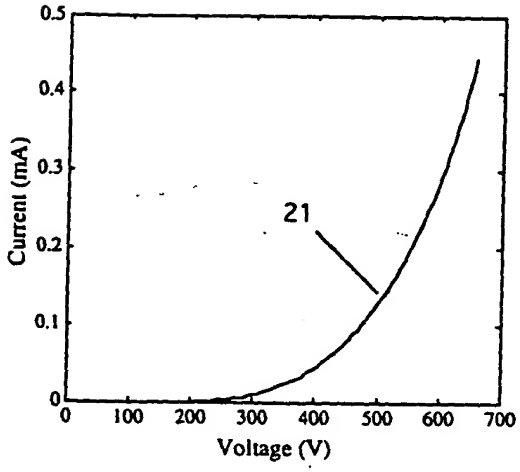

Fig. 2

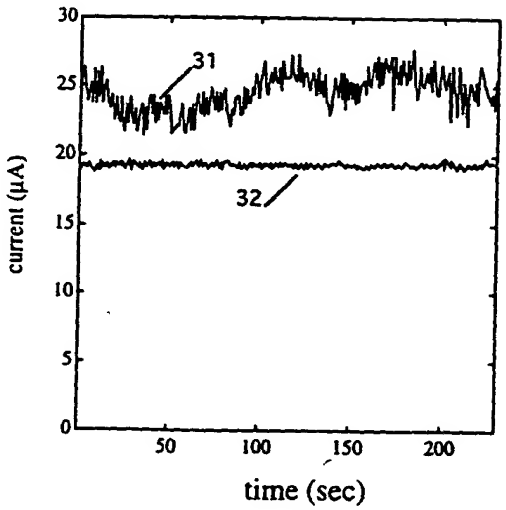

Fig. 3

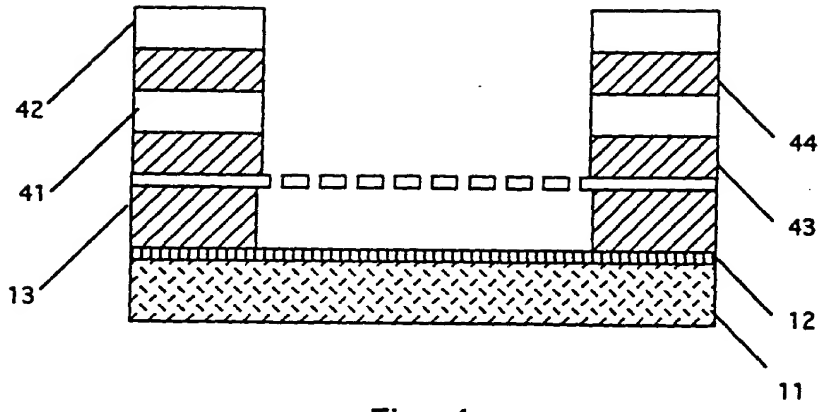

Fig. 4

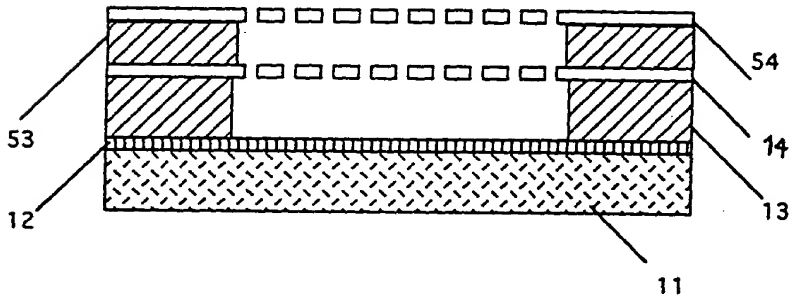

Fig. 5

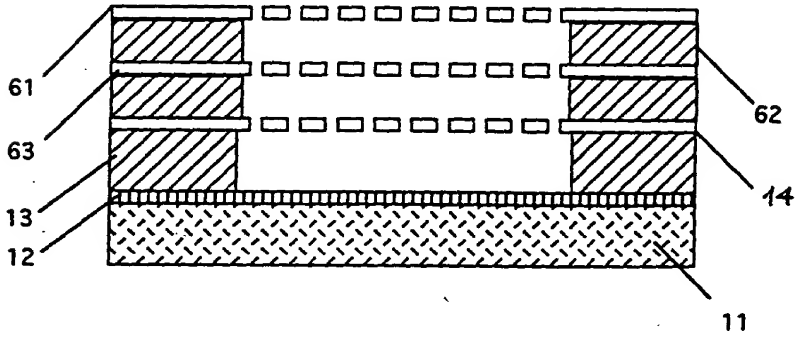

Fig. 6

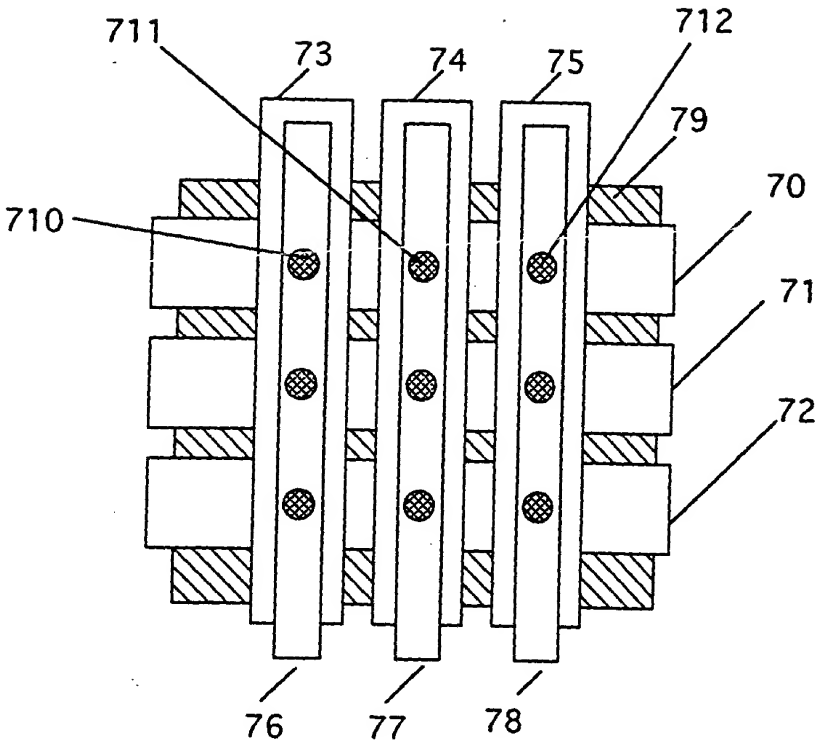

Fig. 7

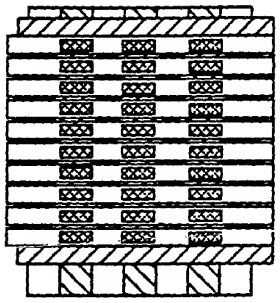

Fig. 8.1

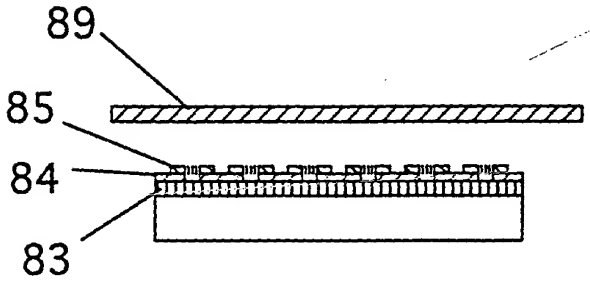

Fig. 8.2

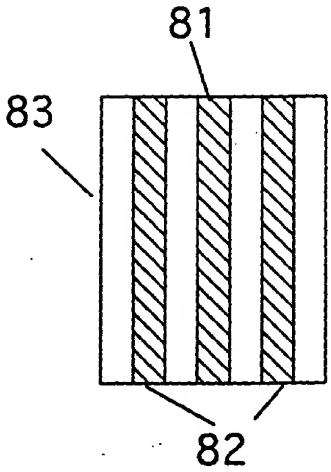

Fig. 8.3

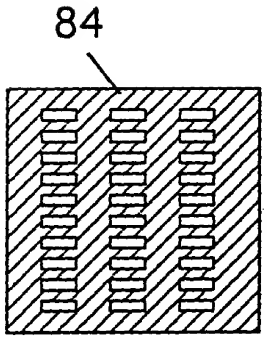

Fig. 8.4

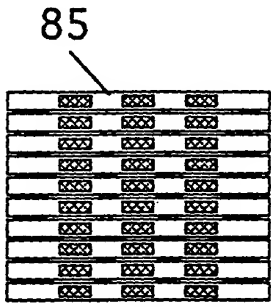

Fig. 8.5

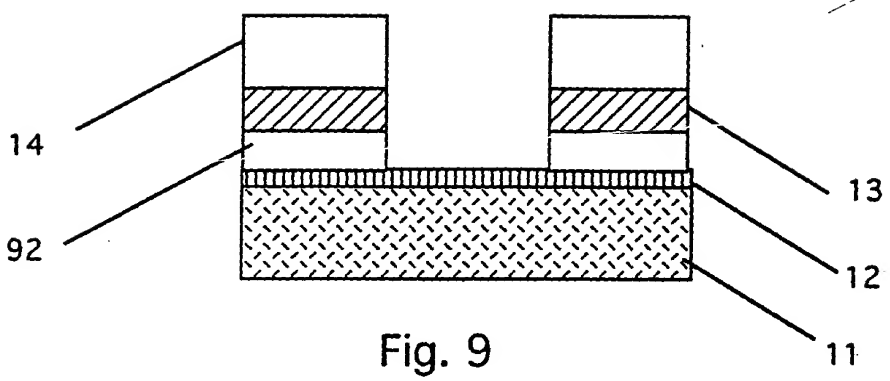

Fig. 9

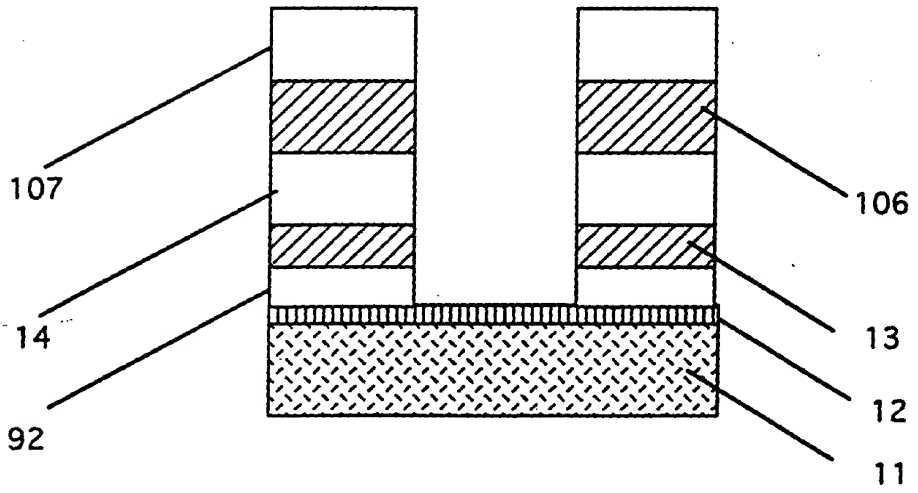

Fig. 10

INTERNATIONAL SEARCH REPORT

International Application No PCT/[redacted] 96/00573

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01J3/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	DE,A,44 05 768 (KEESMANN TILL) 24 August 1995 see column 7, line 64 - column 8, line 31; claims 1-8 ---	1
P,X	SCIENCE, vol. 270, 17 November 1995, pages 1179-1180, XP000574977 W.A.DE HEER: "a carbon nanotube field-emission electron source." see page 1179 - page 1180 ---	1
Y	US,A,3 866 077 (BAKER FRANCIS SIDNEY ET AL) 11 February 1975 see claims 1-11 --- -/--	1,8-11

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 July 1996	17.07.96

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Van den Bulcke, E

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	SCIENCE, vol. 268, 12 May 1995, pages 845-847, XP000574819 W.A.DE HEER ET AL.: "aligned carbon nanotube films:production and optical and electronic properties." cited in the application see page 845 - page 846	1,8-11
A	EP,A,0 596 242 (MOTOROLA INC) 11 May 1994 see claims 1-10	1,9
A	PATENT ABSTRACTS OF JAPAN vol. 94, no. 012 & JP,A,06 331309 (NEC CORP), 2 December 1994, see abstract	1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 96/00573

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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US-A-3866077	11-02-75	GB-A- 1394055	14-05-75
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